

A Study of the Magma Chamber Depths Along the Reykjanes Ridge

Senior Thesis

Submitted in partial fulfillment of the requirements for the

Bachelor of Science Degree

At The Ohio State University

Elise Strecker

The Ohio State University

2012

Approved by

Dr. Michael Barton, Advisor

School of Earth Sciences

Table of Contents

Abstract.....	3
Acknowledgements.....	4
List of Figures.....	5
Introduction.....	6
Objectives.....	7
Geologic Setting.....	7
Methods.....	10
Results.....	11
Conclusion.....	20
Future Work.....	21
References.....	22

Abstract

The research conducted determined the depth of the magma chambers along the Reykjanes ridge. The magma that is being ejected from the chambers along the Reykjanes ridge contains elements important to determining the depth of the chambers, such as MgO, Fe₂O₃, and CaO. These elements are characteristic of certain minerals that crystallize during the cooling of the magma. By determining when and specifically what minerals begin to crystallize it will then be able to be determined at what average depth the chamber is located, along the ridge. This research is being done because there has not been significant research along the Reykjanes ridge. The research was conducted by gathering the data from other papers, and a public database website, it was then placed into an excel spreadsheet and was graphed by using a computer program called CoHort. Once the graphs were created and interpreted, the pressures were calculated using an excel spreadsheet that was created for this specific reason. Looking at the Cohort graphs and interpreting the trends it could be seen at what rate and pressure the specific minerals were crystallizing during the cooling of the magma along the Reykjanes ridge.

Acknowledgements

I would first like to thank my advisor Dr. Michael Barton who has helped me immensely through this whole process. The CoHort Software was a program that I was unaware of how to use and Dr. Barton taught me how to effectively use the software to be able to get the data and conclusions that I was working towards. Secondly, I would like to thank Jameson Scott for also showing me how to efficiently collect data from numerous public databases. I would also like to thank Shell, Exploration and Production Company USA, for their funding during the period of July 2011 to August 2011. Lastly I would like to thank my family and close friends of Kappa Alpha Theta without the help and support from these people I would not have been able to do this project.

List of Figures, Tables and Equations

Figure 1: Location of the Reykjanes Ridge.....	6
Figure 2: Boundaries of the Mid-Atlantic Ridge.....	7
Figure 3: Reykjanes Ridge Depths.....	8
Figure 4: Seismic Activity Along the Reykjanes Ridge.....	9
Equation 1: Calculation of Pressure.....	10
Figure 5: Magma Chamber Depth.....	12
Figure 6: Si_2O	13
Figure 7: FeO	13
Figure 8: CaO	14
Figure 9: FeOT	14
Figure 10: TiO_2	15
Figure 11: Fe_2O_3	16
Figure 12: Al_2O_3	17
Figure 13: P_2O_5	17
Figure 14: Na_2O	18
Figure 15: K_2O	18
Table 1: Pressure and Average Depth Calculations.....	18

Introduction

Iceland contains numerous ridges, as it is known to be an area of high geologic activity. In this paper I will be discussing the characteristics and findings of the Reykjanes ridge (figure 1). Along this ridge and in the surrounding area there are a number of many ridges that experience effects from the plume that is located near the center of the Reykjanes ridge. The research conducted determined the depth of the magma chamber(s) along the Reykjanes ridge. The magma that is being ejected from the chamber(s) contains elements is important in determining the depth of the chamber(s), such as MgO , Fe_2O_3 , and CaO . These elements are characteristic of certain minerals that crystallize during the cooling of the magma (Herzberg 2004). By determining at what depths, and pressures these minerals begin to crystallize by the data on the on Excel spreadsheets, we will then be able to be determine an approximate correlating depth at which the chamber(s) are located.

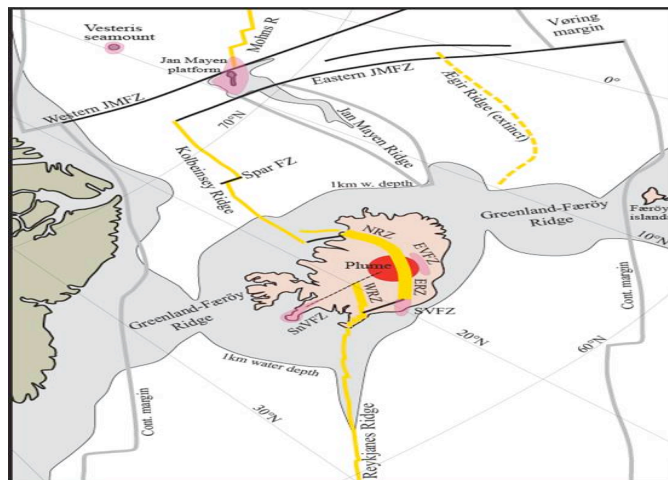


Figure 1: Location of the Reykjanes ridge and its location in relation to other ridges and the plume.

Objectives

The primary objective of this research was to be able to determine the depth of the magma chamber(s) along the ridge. The CoHort graphs of the different minerals crystallizing allows for a determination at what depths the chamber(s) are located. Another objective of this research was to be able to determine exactly how many chambers were located along the ridge. Determining how many magma chambers there are is shown by the Pressure (Kbar) vs. MgO (weight %) graph, which illustrates at what depths the clusters of data are located. By knowing how many clusters of data are shown on the graph, this indicates the number of magma chamber(s).

Geologic Setting

The Reykjanes Ridge is part of the Mid-Atlantic Ridge, which runs for nearly the entire length of the side of the globe. This ridge system also separates nearby tectonic plates (figure 2). The ridge system is massive and cuts very deep into the Earth; one of the deepest places on the ridge for example is the Romache Trench, which has a maximum depth of 25,434 ft (Evans 2002).

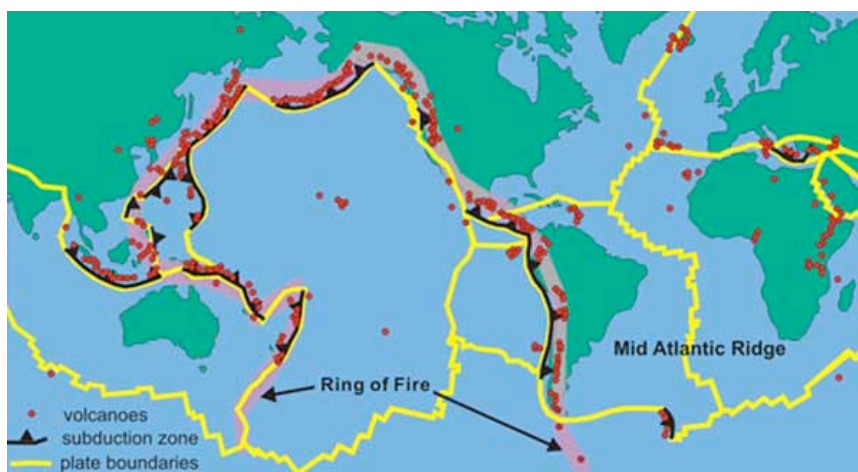


Figure 2: Shows the boundaries of the Mid-Atlantic Ridge as well as the other plate boundaries, subduction zones, and volcanoes.

An interesting aspect of the Reykjanes Ridge is that the ridges are not linear in shape but are however, V-shaped. There has been the idea stated by Benediktsdóttir, Á., R. Hey, F. Martinez, and Á. Höskuldsson that because there is a major difference in the crustal accretion symmetry between the crust immediately off the ridge, and further south. There are two points along the ridge that have been identified as being offset features and have been given the name of ponzu-transforms. These spots support the idea of the rift propagation starting and stopping points (Benediktsdóttir et al, 2012).

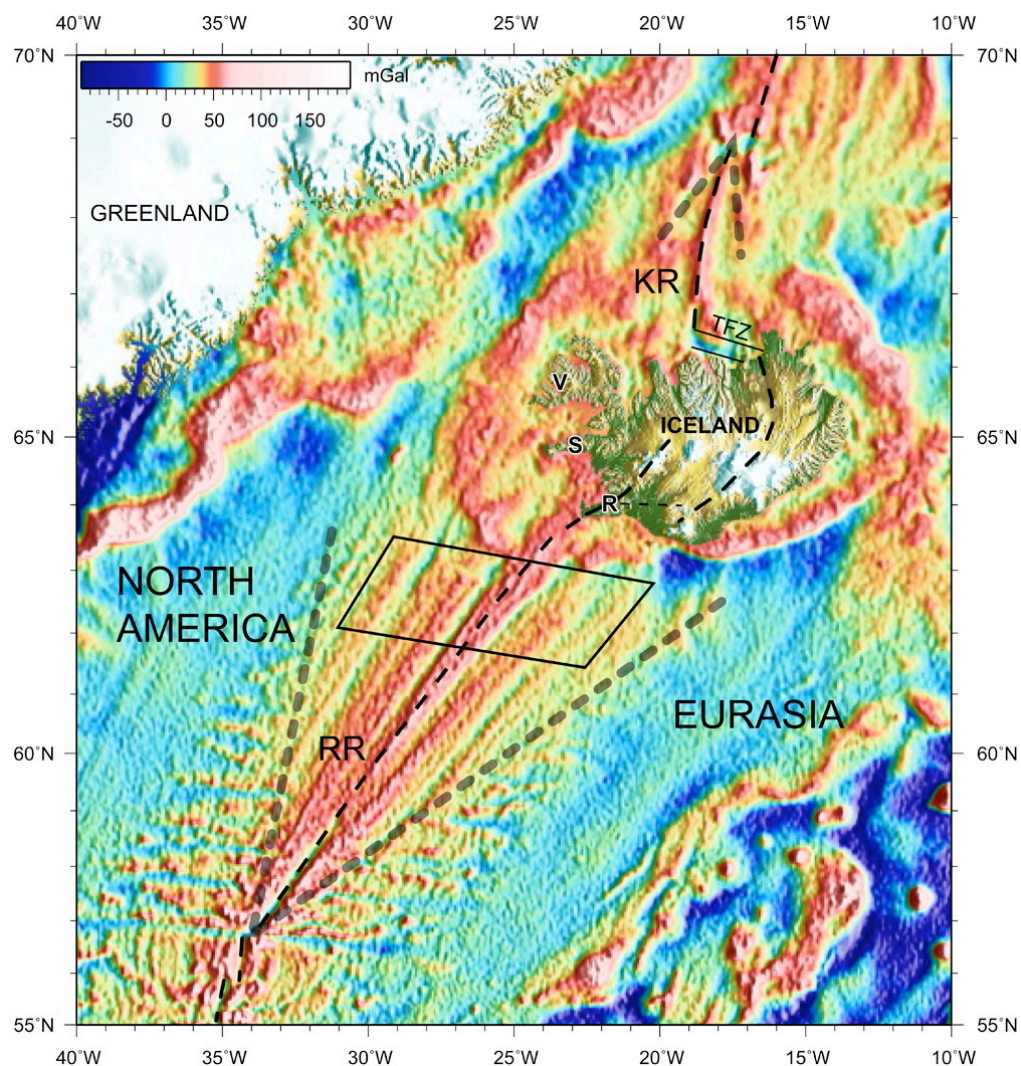


Figure 3: Reykjanes Ridge and the depths at which parts of the ridge are located (Benediktsdóttir et al, 2012).

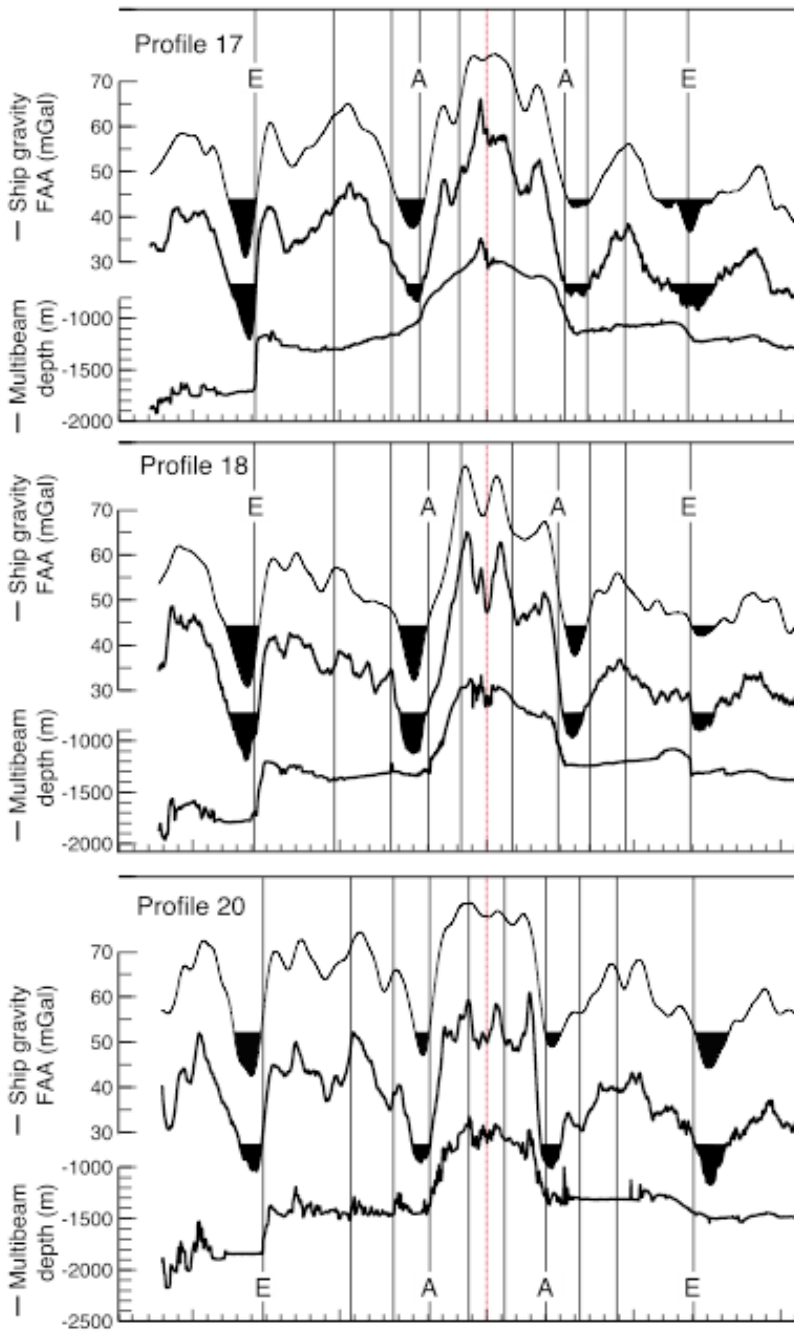


Figure 4: Seismic activity along the Reykjanes Ridge (Benediktsdóttir et al, 2012).

The region of Iceland along the Reykjanes Ridge greatly differs from that of the rest of the Mid-Atlantic Ridge (Benediktsdóttir et al, 2012). For example, there are great differences in the crust near and far away from the ridge, but the Reykjanes ridge also has common elements that one would expect to find in an area of geologic activity such as this (figure 2).

Methods

Excel was a major part of obtaining the results during this research. The data were collected from petdb.org (accessed on 5/8/11, 5/12/11, 5/15/11, 5/18/11, 5/19/11, 5/20/11, 7/27/11) and placed into a spreadsheet, into columns of the same mineralogy. The data that was placed into the spread sheet was then transferred into a program called CoHort, and from there the program generated graphs that allowed us to see how quickly and at what point an element was being crystallized. The second excel sheet that was used was a spreadsheet containing equations that allowed pressures to be calculated. Once the pressures were calculated it could then be determined at what depth the magma chamber(s) were located. When the Excel program calculated the pressure an equation needed to be added, in order to calculate the pressures in Km. The equation is as follows:

$$\begin{aligned} \frac{dp}{dz} &= \rho g \\ \frac{p}{\rho g} &= z \\ \text{Where } p &= \text{Kbar} = 1000 \text{ atm} = 1 \text{ atm} = 10^5 \text{ pa} \\ \rho &= 2900 \text{ kgm}^3 \\ g &= 9.8 \text{ m/sec}^2 \end{aligned}$$

Equation 1: Pressure calculation

Results

The main objective of the research was to determine at what depth the magma chamber(s) were located. It was determined that the average pressure was approximately 2Kbar. By using equation 1 it was determined that the average depth was approximately 7.12Km, (figure 5).

Figures 6-15 show at what rate the weight % of the specific mineral being looked at will crystallize in comparisons to the weight % of MgO. The rates of these graphs are correlated to changing depth and pressures. From these correlations it was determined the approximate depth of the magma chamber(s). The graphs are a select amount of the different common minerals that can be found during the process of the magma crystallizing..

I analyzed specific points on additional graphs that seemed to give an abnormal result and determined if there was an error in the process of retrieving the data from petdb.org. From determining if the point was giving a correct or incorrect result the data point was either thrown out of the set or kept in with an explanation as to why the data point varied greatly from a majority of the other points. The refining of the data points was critical in understanding what the trends the lines on the graphs were exhibiting.

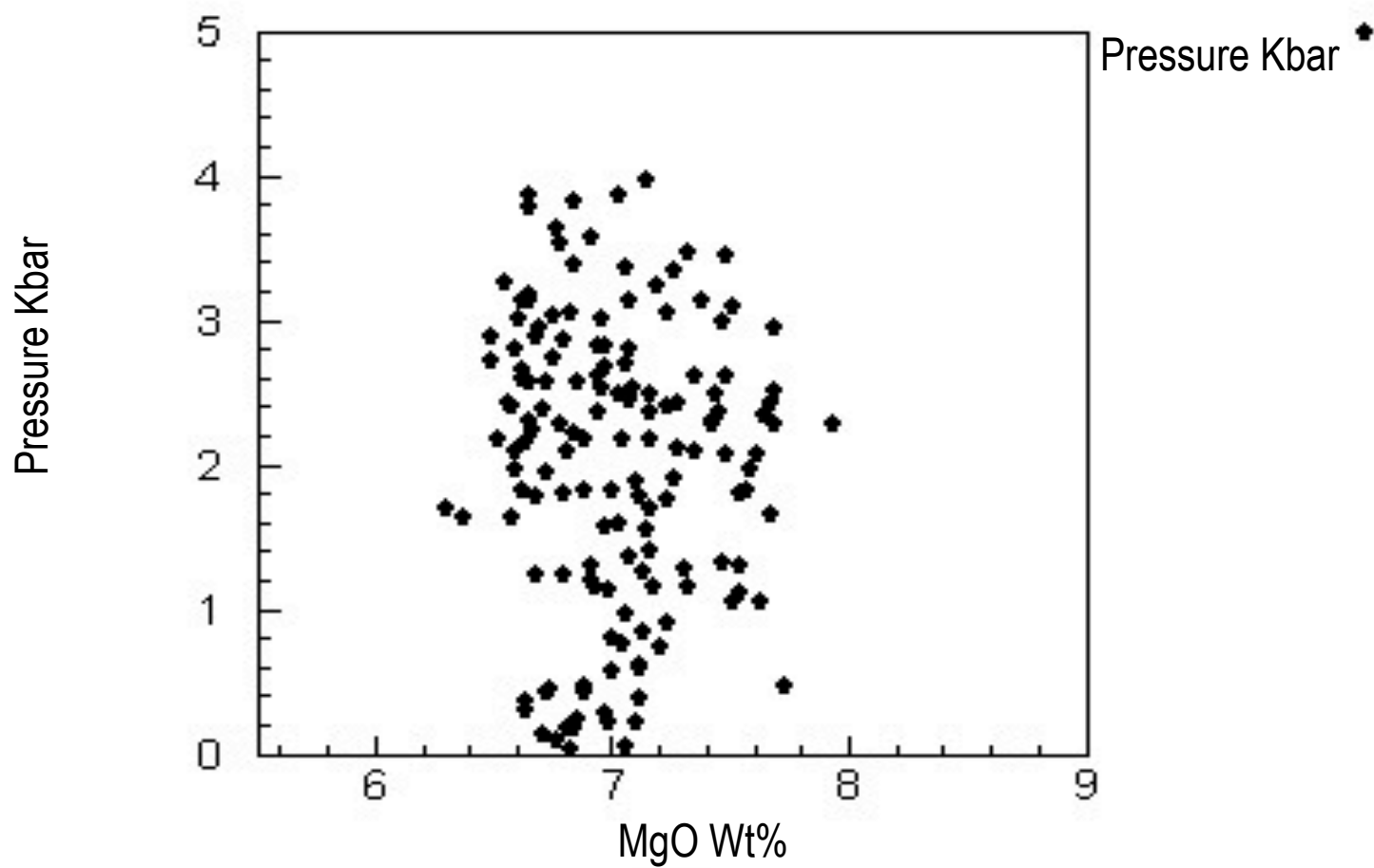


Figure 5: Pressure vs. MgO Wt% shows the average depth of the magma chamber is at approximately 7 km.

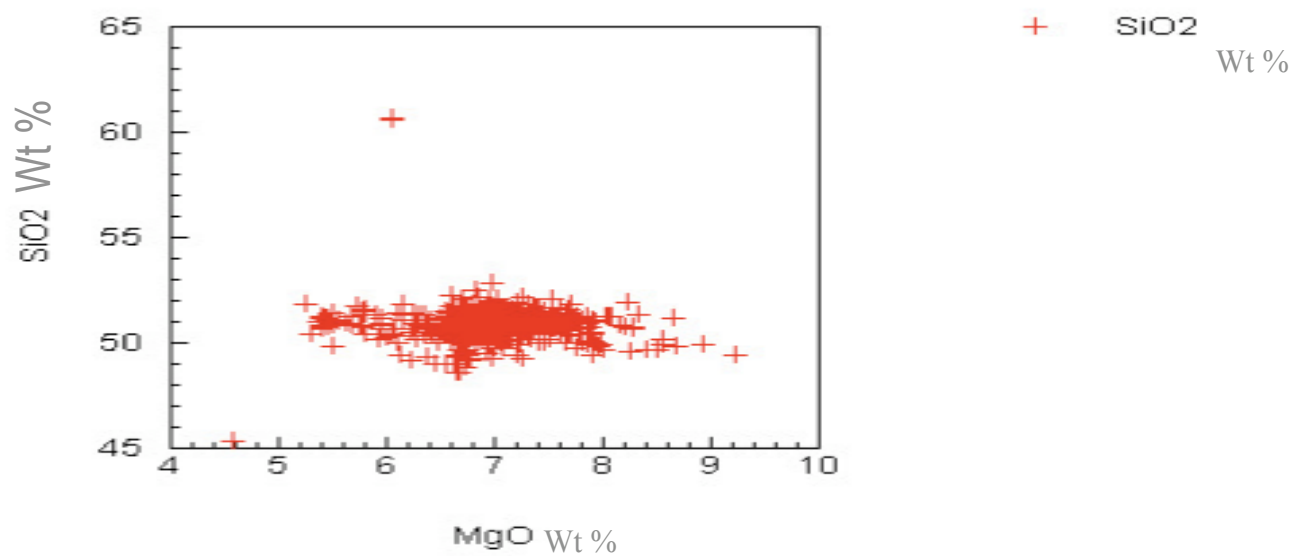


Figure 6: The crystallization rate of SiO₂ Wt% vs. MgO Wt%

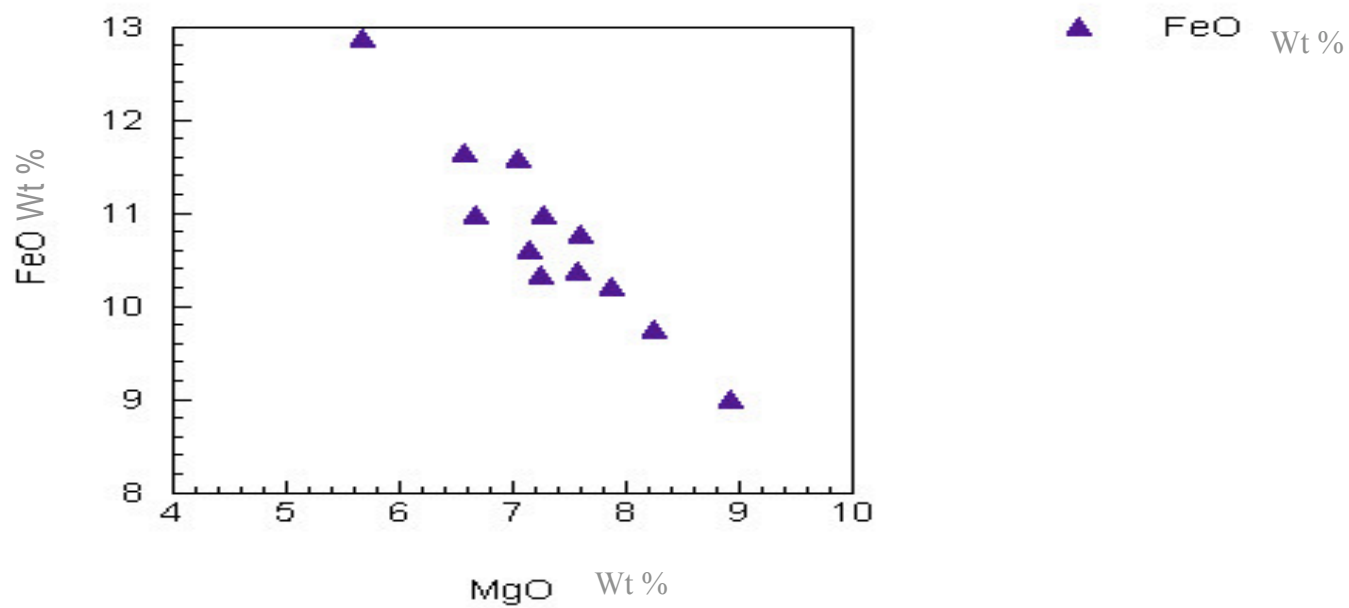


Figure 7: The crystallization rate of FeO Wt% vs. MgO Wt%

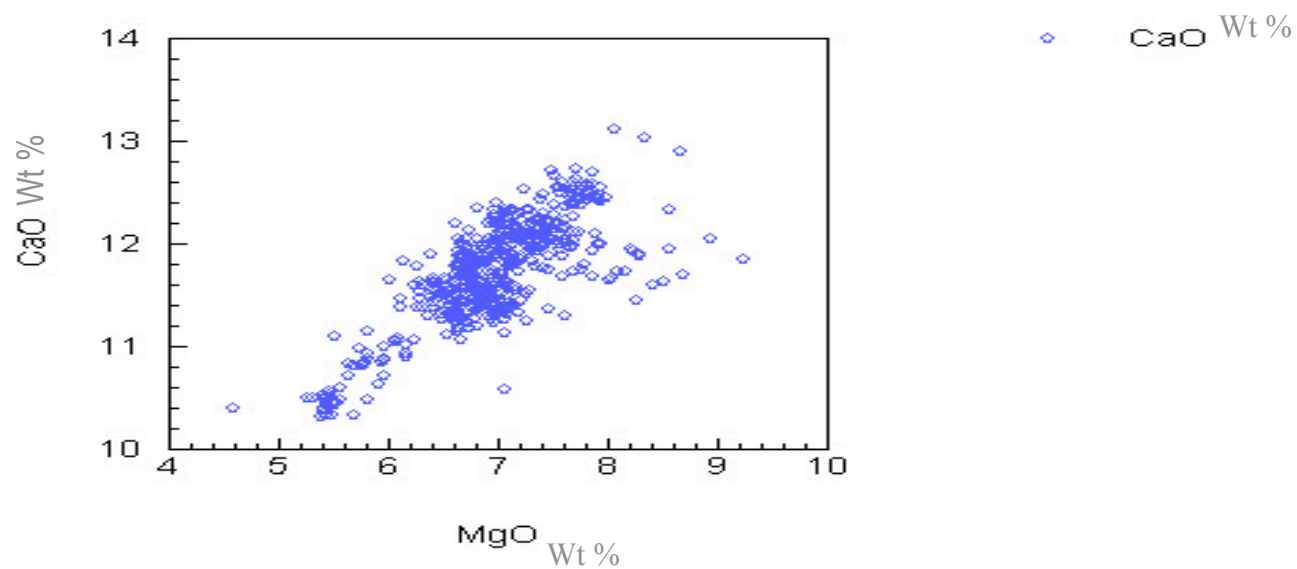


Figure 8: The crystallization rate of CaO Wt% vs. MgO Wt%

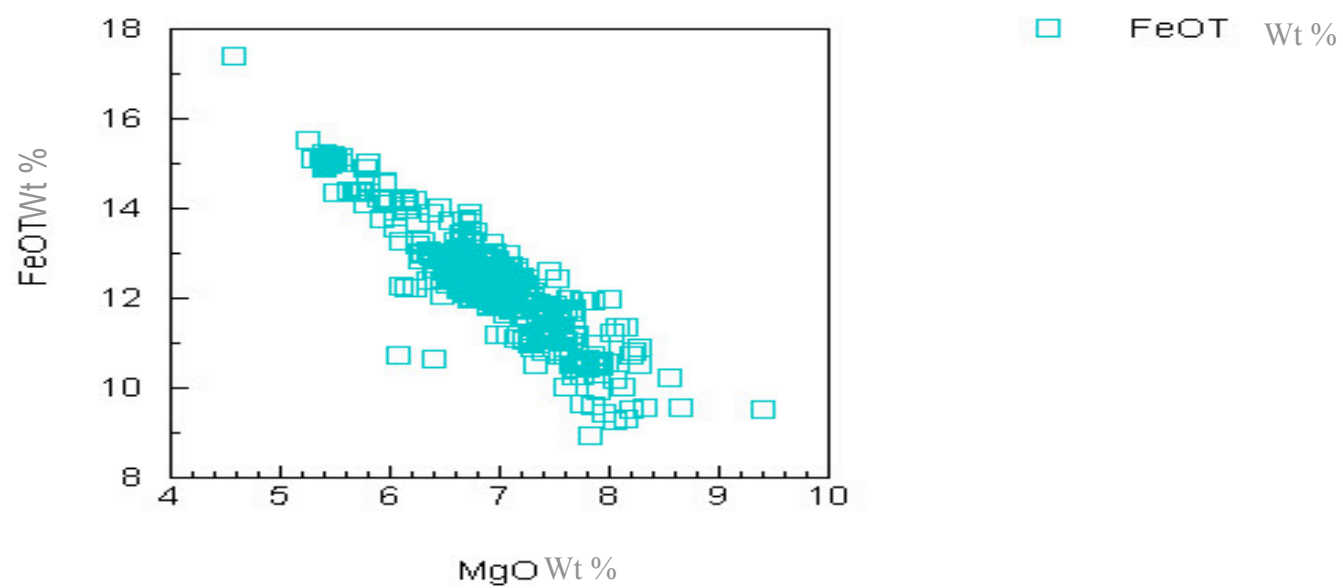


Figure 9: The crystallization rate of FeOT Wt% vs. MgO Wt%

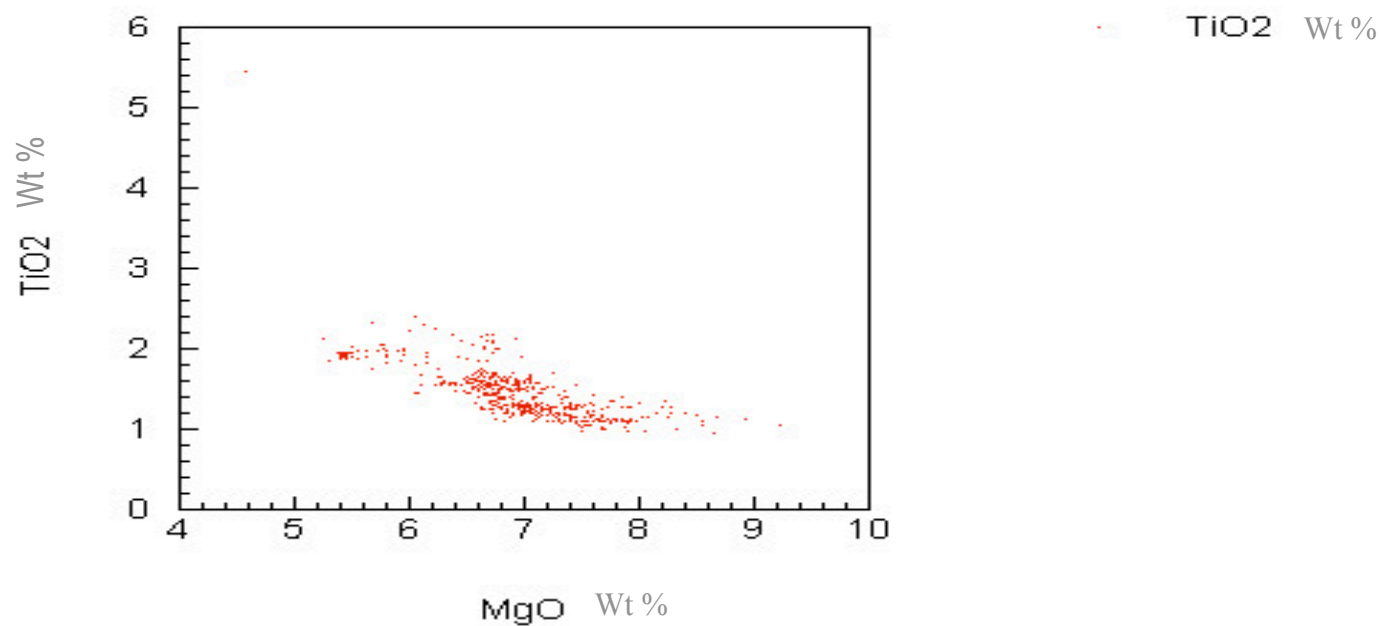


Figure 10: The crystallization rate of TiO₂ Wt% vs. MgO Wt%

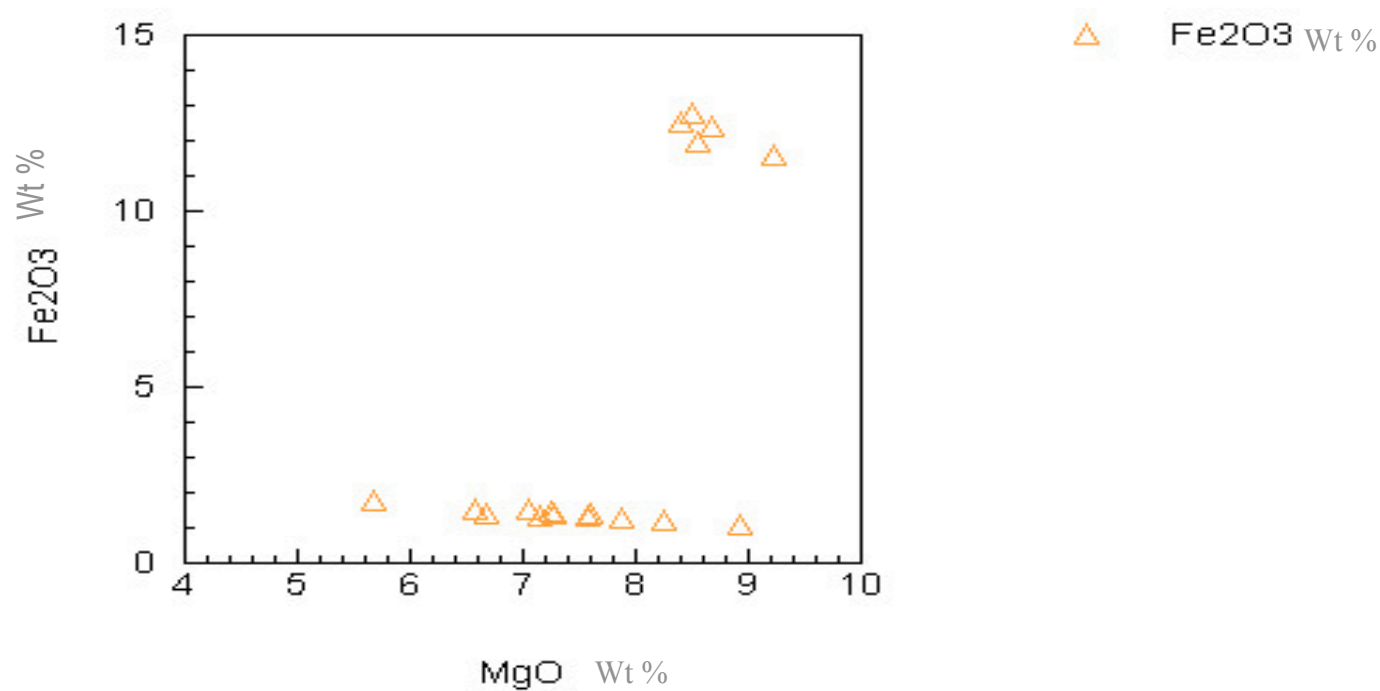


Figure 11: The crystallization rate of Fe₂O₃ Wt% vs. MgO Wt%

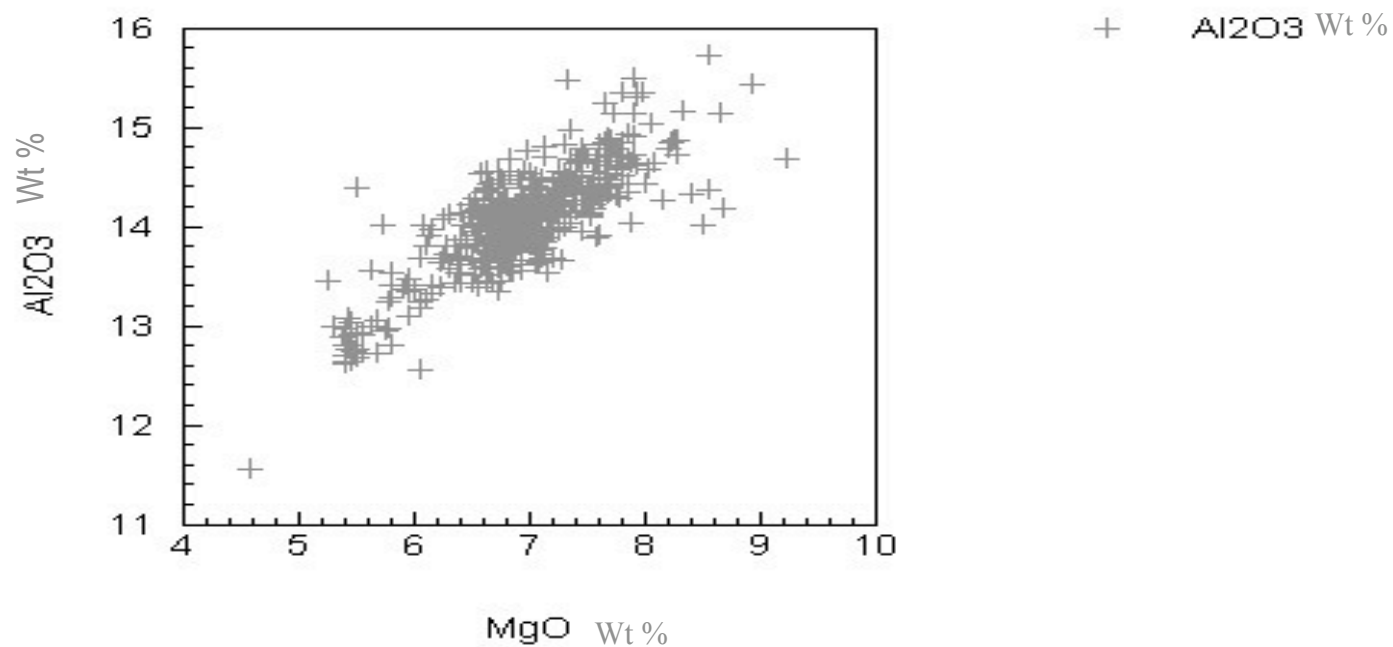


Figure 12: The crystallization rate of Al_2O_3 Wt% vs. MgO Wt%

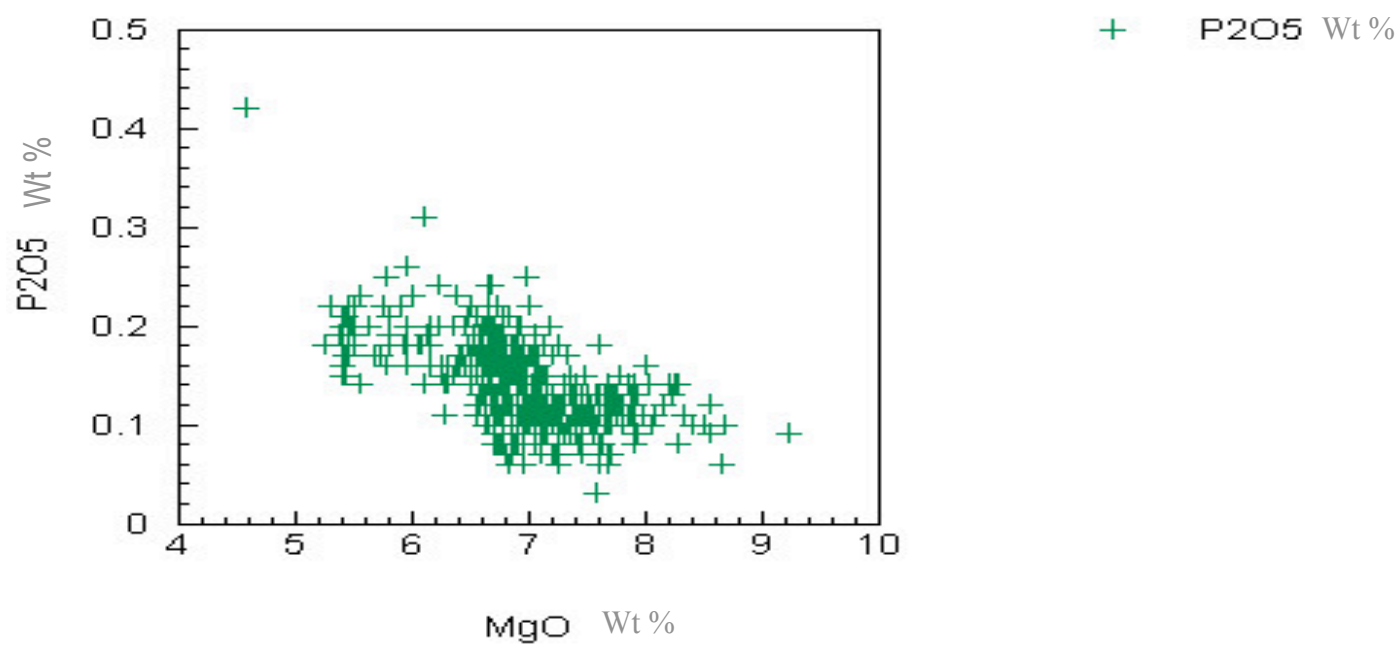


Figure 13: The crystallization rate of P_2O_5 Wt% vs. MgO Wt%

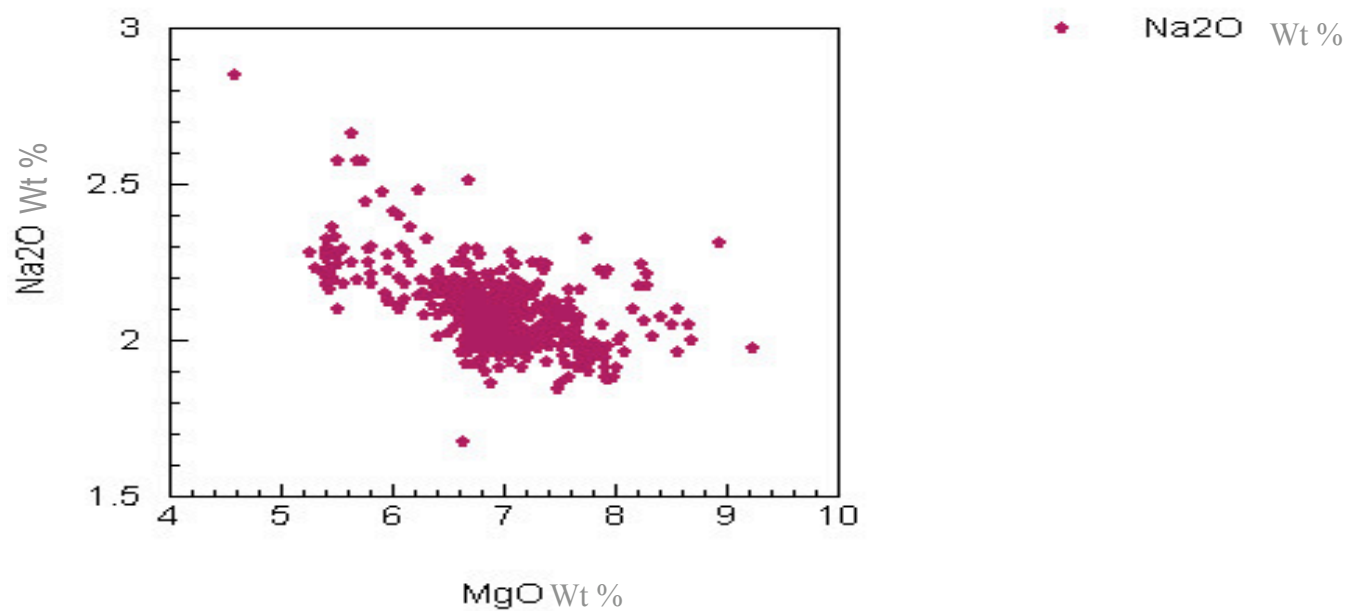


Figure 14: The crystallization rate of Na₂O Wt% vs. MgO Wt%

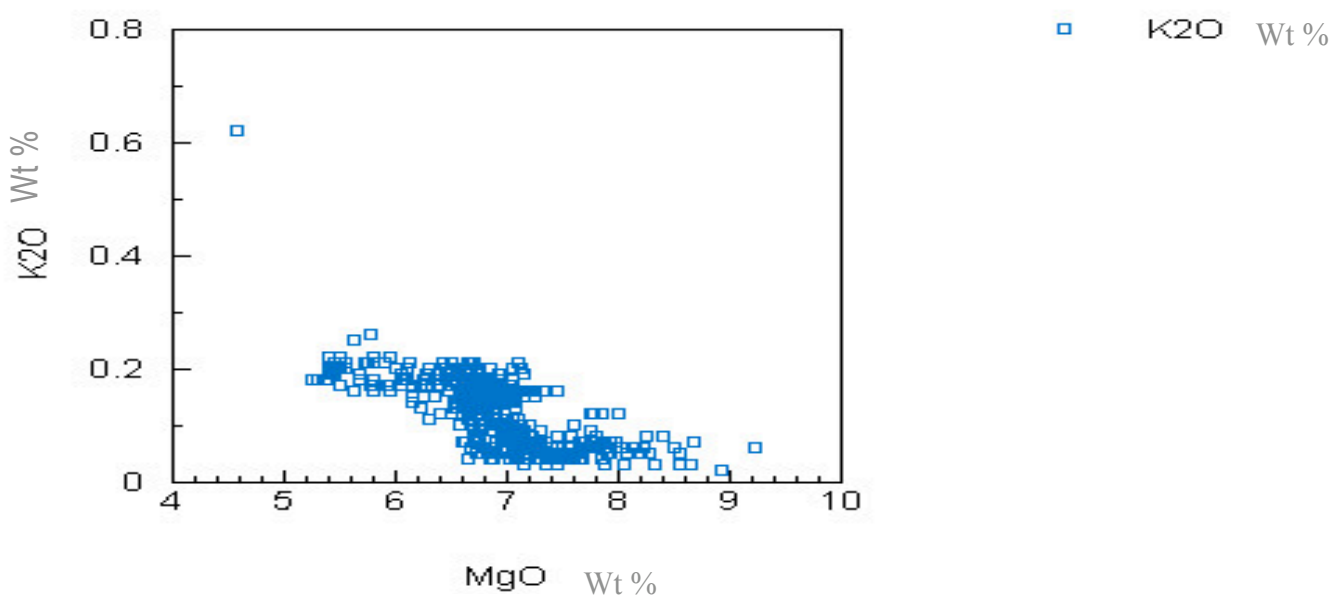


Figure 15: The crystallization rate of K₂O Wt% vs. MgO Wt%

Ave P	1σ	P Ran ge	D pla g-OI	P Ca	DP	T	1σ	Ran ge	T	1σ	Ran ge	Depth Km	Average Depth Km
1.89 95	0.29 92	0.82 40	0.19 25	1.68 55	0.21 40	1175 .40	1.7 5	4.83	1181 .66	0. 88	2.43	6.68369 7057	7.11959 3708
3.14 00	0.15 93	0.45 78	- 0.09 65	2.22 37	0.91 63	1171 .89	0.9 3	2.68	1175 .43	0. 47	1.35	11.0485 5154	
3.01 41	0.12 40	0.32 46	0.01 72	2.38 76	0.62 66	1174 .84	0.7 3	1.90	1180 .49	0. 37	0.96	10.6057 0042	
2.93 96	0.25 94	0.64 34	- 0.16 79	1.81 28	1.12 68	1173 .12	1.5 2	3.77	1180 .89	0. 76	1.90	10.3432 4942	
3.34 18	0.17 66	0.47 78	0.10 00	2.77 54	0.56 64	1177 .22	1.0 3	2.80	1183 .19	0. 52	1.41	11.7586 9133	
3.56 97	0.14 81	0.37 03	- 0.12 13	2.50 41	1.06 56	1178 .86	0.8 7	2.17	1184 .31	0. 44	1.09	12.5605 0891	
2.14 88	0.19 00	0.57 08	- 0.07 03	1.25 24	0.89 64	1167 .18	1.1 1	3.34	1175 .31	0. 56	1.69	7.56072 265	
3.13 30	0.11 71	0.27 04	- 0.00 42	2.43 20	0.70 10	1175 .74	0.6 9	1.58	1181 .73	0. 35	0.80	11.0238 2634	
3.96 82	0.14 20	0.34 81	- 0.11 56	2.94 44	1.02 37	1182 .54	0.8 3	2.04	1187 .13	0. 42	1.03	13.9626 0265	
2.61 55	0.12 75	0.38 01	- 0.05 62	1.67 29	0.94 26	1172 .21	0.7 5	2.23	1181 .42	0. 38	1.12	9.20303 7431	
2.58 85	0.17 47	0.42 19	- 0.11 87	1.42 70	1.16 15	1171 .08	1.0 2	2.47	1177 .31	0. 52	1.25	9.10794 789	
1.64 44	0.21 97	0.66 08	- 0.07 24	0.77 17	0.87 27	1164 .24	1.2 9	3.87	1174 .67	0. 65	1.95	5.78594 3342	
1.77 31	0.28 61	0.82 61	0.18 28	1.40 98	0.36 33	1166 .12	1.6 8	4.84	1176 .09	0. 84	2.44	6.23894 7336	
2.82 11	0.13 33	0.36 75	0.03 04	2.20 48	0.61 63	1172 .20	0.7 8	2.15	1179 .64	0. 39	1.08	9.92655 9428	
2.17 02	0.21 60	0.62 72	- 0.10	1.14 79	1.02 22	1167 .05	1.2 7	3.67	1174 .16	0. 64	1.85	7.63602 5438	

91														
2.53 47	0.17 85	0.42 19	0.02 60	1.95 59	0.57 88	1171 .46	1.0 5	2.47	1178 .35	0. 53	1.25	8.91856 8138		
3.53 13	0.16 00	0.41 34	- 0.12 47	2.60 24	0.92 89	1176 .85	0.9 4	2.42	1181 .57	0. 47	1.22	12.4252 4291		
2.17 55	0.16 53	0.39 03	0.02 76	1.50 62	0.66 94	1169 .61	0.9 7	2.29	1179 .60	0. 49	1.15	7.65498 4208		
2.49 46	0.26 38	0.73 46	0.18 25	2.11 83	0.37 64	1170 .16	1.5 5	4.30	1178 .19	0. 78	2.17	8.77775 843		
2.53 28	0.13 65	0.38 33	0.05 36	1.93 39	0.59 89	1171 .25	0.8 0	2.25	1179 .69	0. 40	1.13	8.91208 9189		
2.36 47	0.14 58	0.38 33	0.04 37	1.77 01	0.59 46	1170 .94	0.8 5	2.25	1180 .90	0. 43	1.13	8.32063 5476		
3.04 18	0.30 06	0.72 09	- 0.19 04	1.79 90	1.24 28	1174 .38	1.7 6	4.22	1183 .17	0. 88	2.12	10.7031 0638		
2.57 73	0.04 65	0.13 85	- 0.01 95	1.54 85	1.02 88	1167 .75	0.2 7	0.81	1173 .23	0. 14	0.41	9.06851 9746		
2.57 93	0.10 29	0.29 69	- 0.05 39	1.55 80	1.02 13	1169 .18	0.6 0	1.74	1175 .83	0. 30	0.88	9.07564 1635		
3.77 71	0.32 74	0.79 61	- 0.22 55	2.34 51	1.43 19	1178 .95	1.9 2	4.66	1183 .60	0. 97	2.35	13.2901 8059		
2.86 74	0.12 97	0.34 16	- 0.08 73	1.84 77	1.01 97	1173 .12	0.7 6	2.00	1180 .54	0. 38	1.01	10.0893 4501		
2.68 82	0.11 56	0.33 02	- 0.06 33	1.70 00	0.98 82	1172 .50	0.6 8	1.93	1181 .73	0. 34	0.97	9.45878 7641		
2.09 55	0.26 12	0.62 14	- 0.15 31	0.80 83	1.28 72	1167 .65	1.5 3	3.64	1178 .23	0. 77	1.83	7.37326 394		
2.45 64	0.09 42	0.25 38	0.02 68	1.65 89	0.79 75	1170 .98	0.5 5	1.49	1179 .72	0. 28	0.75	8.64316 226		
2.09 65	0.18 94	0.51 55	- 0.09 45	0.98 59	1.11 06	1169 .04	1.1 1	3.02	1180 .56	0. 56	1.52	7.37700 4322		
3.05	0.06	0.14	- 0.00	2.25	0.79	1175	0.3	0.84	1184	0.	0.42	10.7370		

15	10	26	84	57	57	.80	6		.22	18		8425
3.37 43	0.08 28	0.19 71	- 0.02 50	2.56 05	0.81 38	1176 .91	0.4 9	1.15	1182 .51	0. 24	0.58	11.8730 507
3.04 44	0.13 06	0.36 31	- 0.08 37	2.04 79	0.99 65	1173 .93	0.7 7	2.13	1180 .19	0. 39	1.07	10.7123 2052
2.69 85	0.12 05	0.34 04	0.07 18	1.94 07	0.75 78	1172 .94	0.7 1	1.99	1179 .82	0. 36	1.00	9.49504 4292
3.14 24	0.08 54	0.21 90	- 0.06 98	2.10 88	1.03 36	1173 .39	0.5 0	1.28	1177 .23	0. 25	0.65	11.0571 6478
3.01 14	0.26 73	0.64 94	- 0.18 05	1.82 26	1.18 89	1174 .06	1.5 7	3.80	1179 .86	0. 79	1.92	10.5961 9988
3.26 14	0.28 78	0.70 92	- 0.20 55	1.94 65	1.31 49	1175 .37	1.6 9	4.15	1180 .75	0. 85	2.09	11.4756 1497
2.71 01	0.20 20	0.49 86	- 0.15 14	1.50 01	1.21 00	1171 .71	1.1 8	2.92	1177 .09	0. 60	1.47	9.53605 3568
2.39 75	0.22 54	0.53 78	- 0.14 47	1.18 73	1.21 02	1169 .43	1.3 2	3.15	1177 .54	0. 66	1.59	8.43603 3141
2.42 91	0.14 31	0.38 31	- 0.09 20	1.40 48	1.02 43	1168 .63	0.8 4	2.24	1176 .09	0. 42	1.13	8.54718 9286
1.93 96	0.08 96	0.24 11	0.00 62	1.05 53	0.88 43	1165 .35	0.5 2	1.41	1175 .33	0. 26	0.71	6.82474 6541
2.88 32	0.19 54	0.47 94	- 0.15 27	1.66 08	1.22 24	1173 .43	1.1 4	2.81	1181 .27	0. 58	1.41	10.1448 0254
1.63 19	0.18 43	0.46 08	- 0.11 47	0.28 02	1.35 17	1164 .03	1.0 8	2.70	1173 .98	0. 54	1.36	5.74193 0432
1.80 61	0.02 48	0.06 28	0.03 47	0.84 19	0.96 42	1166 .11	0.1 5	0.37	1176 .56	0. 07	0.19	6.35502 7568
2.29 34	0.15 31	0.36 84	- 0.09 92	1.14 65	1.14 69	1169 .34	0.9 0	2.16	1177 .09	0. 45	1.09	8.06949 3489
2.27 31	0.03 85	0.09 49	0.01 40	1.37 76	0.89 56	1168 .74	0.2 3	0.56	1175 .94	0. 11	0.28	7.99828 5067

Table 1: Calculation of the average depth of the magma chamber by using average pressures.

Conclusions

Our data shows that by observing the trends in the crystallization of the minerals through figures 6-15 that there is only one magma chamber known at this time in the research (figure 5) (Kelly and Barton 2008). The next two conclusions were made by interpreting the data off the results of the pressure calculations from the Excel calculations. The average pressure of the magma chamber from the data was about 2 Kbar. From this data we were able to interpret at which depths in the Earth that that pressure would correlate to. The results yielded the conclusion that the average depth of the magma chamber was located at about 7.12 km (table 1).

Future Research

My future research consists of going back through the data and making sure that all of the new data points that I will be collecting from the database have all the components of being considered good data. I would also like to be able to collect more data from different parts of the ridge. For future use of CoHort I would like to be able to create statistical graphs in order to have a greater understanding of the crystallization of the magma, and depth of chamber(s).

References

Benediktsdóttir, Á., R. Hey, F. Martinez, and Á. Höskuldsson (2012), Detailed tectonic evolution of the Reykjanes Ridge during the past 15 Ma, *Geochem. Geophys. Geosyst.*, 13, Q02008, doi:10.1029/2011GC003948.

Evans, Rachel. "Plumbing Depths to Reach New Heights: Marie Tharp Explains Marine Geological Maps." The Library of Congress Information Bulletin. November 2002.

Herzberg, Claude. "Partial Crystallization of Mid-Ocean Ridge Basalts in the Crust and Mantle." *Journal of Petrology*. 45.12 (2004): 2389-2405. Print

Kelley, Daniel, and Barton, Michael. "Pressures of Crystallization of Icelandic Magmas." *Journal of Petrology*. 49.3 (2008): 465-492. Print.

"Download Data." *PetDB Petrological Database of the Ocean Floor*. National Science Foundation, 07/2011. Web. 1 Sep 2011. <<http://www.petdb.org/>>.